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HIGH PRESSURE VESSELS OF LIGHT-WATER COOLED AND-MODERATED POWER REACTORS

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1. INTRODUCTION

The high pressure vessels of light-water cooled and moderated high-power reactors have been designed in the USSR for the New-Voronezh Atomic Power station, for the APS in the German Democratic Republic and for the Ulyanovsk Experimental Industrial APS. In designing the reactor vessels provision has been made for a complete cycle of vessel fabrication in order to only mounting and assembly works and connecting of the communications to accomplish at site as well as for transporting these vessels to the site of mounting by railway heavy cars.

In accordance with specifications the life of these vessels should be 20 years, that was the main problem of the whole design and development works.

2. MAIN FEATURES OF HIGH PRESSURE VESSELS

Difficulties in designing and manufacturing the vessels of large pressurised water power reactors operating under high pressure has been dictated by the following specific conditions:

- by the high operating pressure of the coolant, so that it at higher diameter value results in significant thickness

of the vessel walls. This condition has made the solution of technological and welding problems more difficult; it is associated with the increase of stresses caused by pressure differences especially at variable duties;

- by the high temperature of the coolant; by a considerable volume of the primary circuit and consiquently by a higher amount of the stored energy which may lead to a serious danger in case some damage takes place somewhere in the vessel seal;

- by the presence of radiactive radiation causing some additional temperature difference in the vessel wall at a level of the core and a change in physical and mechanical properties of the metal during of operation, and consequently by the necessity of periodic checking the change of these properties;

- by vessel loading conditions associated with the periodical change in the load induced by pressure and temperature.

The number of loading cycles for a culculated and experimental determination of the vessel material workability within the above said period of life has been estimated with the assumed following conditions:

1) with pressure fluctuations within ± 5 kg per sq.cm at a steady operating duty because of some non-ideality of the automatic control system functioning at the set power level, i.e. by the value of 10^4;

2) with the same condition as the above mentioned but with pressure fluctuation within ± 7 kg per sq.cm at transient operating duties i.e. by the value of 10^3;

3) with pressure drop to the atmospheric level and temperature drop to 60–70°C at sheduled and emergency shutdowns of the reactor with after-heat removal, i.e. by the value of 200 cycles;

- by inaccessibility of the major part of the vessel elements and joints for their repair and inspection after the reactor operation is commenced;

These features of the high pressure vessels have necessitated to put forward additional requirements for their

design, choice of steel, and technology of fabrication, the requirements which are more strict than those of the Gostekhnadzor[x)] so far as in general the design of steam boilers and vessels operating under pressure is displayed in the USSR by rules and standards of the Gostekhnadzor.

As a metal for the fabrication of the reactor vessels of high dimentions a standard boiler steel can be used as well as a special steel having higher mechanical properties. Since it has been decided to fabricate the reactor vessels at the plant, because this provides better quality, reduces their weight, and makes their transportation to the site easier, the alloyed steel proposed by prof. Pashkov and engineer Teplova has been chosen; the use of this steel enables to reduce a vessel weight twice. As for welding there have been taken the materials proposed by two engineers, namely: Molchanova and Ivanova. The chosen chromium-molybdenum-vanadium steel posesses high strength and plastic properties. For example, its yield limit at the operating temperature 50 kg per sq.cm, the strength limit 70-80 kg per sq cm at relative extention 20%, and shock viscosity is not less than 10 kg per sq.cm. In this connection it is the chemical composition that has made it possible to obtain homogenous mechanical properties throughout the whole cross--section of the vessel. Besides of these high mechanical and plastic properties this steel possesses high heat-resistivity at the operating temperature and allows overheating up to 450°C. The steel also has all the required technological properties, i.e. weldability, a good ability of being plated with a layer of the other metal and it enables to make forgings up to 100 tons and heavier as thick as 600 mm.

In designing the reactor vessels a number of specific requirements have been observed.

The ring-shaped portions or simply ring portions of the vessel are made as forged without longitudinal seams.

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x) the state agency which works out and issue rules for the design and construction of the industrial istallations and exercises inspection of their operating conditions.

Taking into consideration the unadequite possibility of checking the reactor vessel when in operation the inlet and outlet nozzles for water which cools the core,have been positioned in the middle relatively accessible part of the vessel. Thus it increases the reliability of operation from the viewpoint of dewatering the core.

The electrically welded seams are specified as the complete-penetration welds throughout the metal depth and equal to the base metal in strength. At the places where welds can be made only as a single standard seam the subsequent machining of these welds has been provided.

The nozzles have been welded with the double seam. With such a design if one sealing seam is damaged the other one takes on the functions of the first seam, and only then the second seam failes the media can leak into the atmosphere. There are some measures provided for the units made of steel with different linear expansion coefficients in order to relieve additional stresses under operating condition by introducing thermal strain.

Taking into account the necessity of maintaining an adequate purity of the coolant it has been decided to plate the internal surface of the vessel by the austenitic stainless steel.

At the same time having in view that the vessel surface forms only insignificant part /about 1%/ in the total surface of the primary circuit, that is determined mainly by the total surface of the pipes of the steam generators, comprehensive investigation of the vessel steel for corrosion resistivity and the choice of optimal water condition, which both provide a minimal pollution of the circuit with corrosion products, have been made.

From the results of these investigations it has become clear that the corrosion resistivity of the chosen sort of steel is sufficient to do away plating the steel for the future.

The dimentions of the vessel have been determined in general by the reactor principal scheme, i.e.

- the internal diameter - by the core dimentions resulting from physical and thermal calculations and by the thickness of the screen preventing the metal of the vessel from radiation damage;

- the height - by the adopted way of controlling the reactor power, by the technique of recharging as well as by the height of the layer above the core to provide necessary biological protection of the upper part of the reactor;

- the thickness of the elements - by the calculations strength according to the standards of the Gostekhnadzor for given operating conditions; in special cases and for elements to which the recommendations of the Gostekhnadzor can not be valid by special technique worked out on the basis of the theory of elasticity.

3. THE NEW-VORONEZH APS REACTOR VESSEL DESCRIPTION

The vessels for the three light-water cooled and moderated power reactors have been developed and fabricated on the basisof similar principal solutions that has made it possible to reduce the amount of experimental and technological work and to direct much attention to their depth and quality.

The reactor vessel mounted at the New-Voronezh APS is shown in Fig. 1.

It is a vertical cylindrical vessel with the elliptical bottom and the flat cover.

By height the vessel is devided into three zones.

The lower zone 6000 mm high and 3800 mm in outer diameter with the wall 100 mm thick is welded to the elliptical bottom 120 mm thick. The lower part consists of the three ring portions, each forged as one piece. There are no nozzles or perforations in the lower zone.

The middle zone 2900 mm high consists of the three forged as one piece ring portions, each 180 mm thick and 3880 mm in outer diameter. On the outside the lower ring portion has a ring-shaped projection serving as a support of the vessel. There are 12 water inlet and water outlet nozzles of "Dy 500" type in the lower and upper ring portions of the middle zone by 6 in each.

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The upper zone is a forded as one piece flange 1100 high and 3900 mm in outer diameter. A strengthening ring is set on the upper ring portion /the flange/ with strain ,the former lessens the flange deformation caused by the bulging force of a wedge-shaped seal and consequently bending moments in the vessel studs and in a welded seam of the flange; there is also a slot for the cover seal in the upper ring portion. The necessity of setting the strengthening ring on the flange has been dictated by technological difficulty of fabricating the flange 500 mm thick. The sealing of the joint in between the cover and the flange is made as a self- sealing lock with a nickel gasket. The gasket is pressed in between the cover and the flange by means of studs through the thrust ring. The value of the summary force of tightening the studs is assumed to be equal to 1,25 - 1,5 of that of, the pressure force effecting the cover. In order to compensate tolerances permissible in the fabrication of the studs, nuts and thrust ring spherical washers had been placed under each nut by two. The slipping action of the washers when a nut is being tightened (during the assembly work), prevents the studs from bending. Having no experience of operating this wedge seals of such a large size regardless of the positive test results it has become necessary to make the emergency (reserve) seal. The principal part of this seal, a half-a-torus compensator is welded with one side to the vessel flange and with the other side to the welded metal of the cover (Fig. 2).

The emergency seal and the wedge seal are completely interchangeable, and the use of a flexible element in the half-a-torus enables to compensate force and heat deformations of the vessel flange and the cover.

The measuring devices provided to determine the joree of tightening the studs. Their principle of action is based on the control of the stud extention. These devices allow to measure the value of tightening force with the accuracy of 5 + 10% (Fig. 3).

The vessel cover is made as a forged flat plate 500 mm

thick and 3350 mm in diameter. It has 55 throughout perforations, 90-2000 mm in diameter, on which the tubes housing monitoring and measuring devices are positioned. These tubes are made as double "bells", one inside the other, and their welded seams connecting them with the cover are shifled aside from the zone of maximal concentration i.e. placed at some distance from thepe perforation contour.

The internal surface of the vessel is covered with the anti-corrosion welded metal made by the austenitic electrodes manually or automatically by bands. The welded metal is around 20 mm thick.

The fabrication, test assembly and hydro-test have been accomplished entirely at the manufacturing plant.

In developing the reactor vessel the attention was payed to make it reliable in operation, that is why a series of measures controlling the vessel behaviour in operation conditions have been provided. Among them the installation of 24 channels in the vessel for loading test samples made of the same material of what the vessel details are made. It is possible to extract periodically these samples checking on a change in mechanical and plastic properties of the vessel metal and a shift of the critical temperature of imbrittleness.

There are several tensometers installed at the points the most sensitive to the change of the temperature condition to control the stressed state of the vessel.

These points are at the stud steam and welded joints between the flange and the ring portion of the middle zone.

The tensometers positioned on the studs are connected to the instruments provided with self-recorders and sound signals. There is a special monitoring system provided to control the thrust ring heating-cooling, this system levels the temperature difference of the flange and the thrust ring thus lessening additional stresses in the studs at transient operating conditions the reactor start-up and shut-down).

The use of this system enables then necessary faster heatup or cooldown the reactor than it is stipulated by

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the operating instruction.

The ways of solving the problems acossiated with the construction of large vessels being shown in the description of the New-Voronezh APS are universal only in their principal part.

Considering each-reactor being specific in its character seperate elements of the vessel may differ by their constructional make up or by way of designing some units. For example, it is due to relatively law stressed state of the vessel at the New-Voronezh and Ulyanovsk Atomic Power Stations the flat easy-fabricated cover is used, but the cover for the reactor supplied to the German Democratic Republic is made as spherical one (Fig. 4.). It is caused by the fact, that the reactor in the GDR was design to allow recharging without taking the cover off; that made it necessary to enlarge the diameter of cover perforations. The spherical cover allows to make recharging maintaining a lower level of stresses.

The reactor designed for the Ulyanovsk APS is a boiling water reactor, that is why at mounting work it has been provided by additional measures to make the vessel nozzles with heat protection.

4. RESEARCH WORK

Together with a high amount of design and calculation work the adopted research program to study the stressed state of the vessel under stationary and non-stationary operating duties, to study the strength of the base and welding materials chosen for the vessel fabrication as well as to check on the sealing ability of the joint between the cover and the vessel flange has been cerried out.

The whole program is phased as follows:

1. Checking on the stressed state of the vessel on plastic models by tensometers and on the resin models by an optical method.

2. Checking on the stressed state of the vessel on steel models under operating conditions with simulating non--stationary conditions of the vessel operation.

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3. The investigation of the chosen materials for their strength under operating conditions.

4. The investigation of the ability of the cover seal to endure high pressure on a full size stand imitating the upper part of the vessel; a final ajusting auxiliary devices to serve the sealing unit and monitoring system.

5. The control checking on the stressed state of the vessels the shift of their elements during the period of hydraulic tasts at the manufacturing plant.

A certain phase of experimental work and their main result are described in brief below.

Checking on Vessel Stressed Condition on Plastic Models

The stresses within the region of coolant inlet and outlet nozzles and stresses in the upper part of the vessel as the function of bulging force at tightening the wedge-shaped sealing gasket as well as the stresses caused by the strengthening ring tightly set on the vessel flange have been determined at that stage. Bendings and stresses in the cover at the site of the wedge-shaped gasket and near perforations have been thoroughly studied. Studies have been made on the model fibre glass built 1:20 and on the models of hypocside resin.

The experimental results has confirm that all details of the vessel work within elastic region and have a sufficient excess in elastic properties to provide a non-stationary operating duty when additional thermal stresses occur. In the bottom cover rather significant bending moments reaching 25% of a membrane stresses have been found.

They have not been considered by the bottom calculation technique. The model design and the diagram of stresses are shown in Fig. 5. The calculated data with bending moments caused by pressure considered positively agree with the data obtained by tensometerying the full-size vessel.

Checking on Stressed State of Vessels on Steel Models

Preliminary empirical strength calculations have shown

that with a rather complicated shape of the vessels, with details of high thickness and different cross-section to be connected considerable stresses may occur at startup or shuttdown reactor with subsequent cooling it down. To check stressed condition the steel model 1:4,5 (Fig. 6.) was made and subjected to various tests. It was pressurized to 100 kg per sq.cm and heated by an electric heater. After heating the contained water to 275°C, it was discharged with simultaneous introducing the cold water in from a buffer tank; this resulted in mixing the both waters at the inlet. The rates of cooling the water in the model were chosen as those proportional to the square value of the scale, i.e.

$$b_m = b_n \times m^2, \text{ where:}$$

b_m; b_n - are water cooling rates in the model and in the full size vessel correspondingly;

m - is the model scale.

Heat-resistant tensometers with 10 mm base were used to register stresses. They were positioned both inside the model and on the outside in special protective casings. Data was recorded by potentiometers with 2 sec. interval.

The analyses of the data obtained shows that the stresses at the vessel nozzles are decreasing at cooling the model vessel. down,that the chosen cooling rate of 30°C per hour is permissible for a given vessel design because it does not induce stresses exceeding the yield limit of the base metal and bending moments of the cover exceeding the permissibde moments caused by the control system mechanisms installed on the cover.

Also they prove to the fact that the model seal operates well enough despite its sealing surfaces intershift perceptibly one upon the other.

Strength Test of Chosen Materials under Operating Conditions

The number of possible operating duties as well as those of emergency at which vessels are being effected by

their internal pressure, level of power and heat load at the maximal degree and at the same time has been determined on the basis of a given period of life of the vessel. The task set to investigate the strength of materials has been solved in the aspect of:

- testing standard samples of the base material, of the welded metal surface cover and welded joints for strength;
- testing material samples having been irradiated in the channels of the experimental reactor;
- repeated-statical testing small dimentional sampdes;
- repeated-statical testing the samples corresponding in size to the actual details of the vessel up to 500 mm in thickness (Fig. 7.);
- testing samples to determine the critical temperature of imbrittlement and the shift of this temperature depending on the size of a detail, and the degree of irradiation;
- testing samples with the welded metal cover for heat shock with 300°C temperature drop;

As a result of the programme carried out it is found that the materials accepted for the design possess sufficient heat resistivity and slightly change their properties being irradiated by an integral neutron flux which corresponds to the material wear during the 20 year period of vessel operation. The repeated and statical tests have shown, that the existing level of stresses in the vessels with their concentration considered is permissible for the given period of operation with 10-fold margine of safety estimated in the number of the reactor cycle-shut-down.

Investigating the significance of critical temperature of inbrittlement, it has been found that the most thick details, i.e. the cover and the flange cause some limit in the vessel performance because their critical temperature of imbrittlement is within +50 - 80°C at their initial state. The same materials have been studied under irradiation; their critical temperature of imbrittlement is growing to 100--120°C with an increase of their integral dose of irradiation.

Since the ability of the vessel to carry high pressure has not been lessened, what is proved by the resudts of investigations, the vessels have been tested hydraulically by cold water and at the site by water heated to 80-90°C. For

the future it is decided to raise the pressure also with the warm water in the circuit.

As it was shown above, design vessel nozzles in assembly with austenitic steel sleeves having their linear coefficient of extension 17.10^{-6} $1/^{0}C$, and a nozzle itself is made of steel with 12.10^{-6} $1/^{0}C$ linear coefficient of extension.

The check up of the nozzles of this type for strength has been exercised at a special experimental plant where a nozzle of actual size has been subjected to the periodical change of temperature simultaneously carrying stresses induced by internal pressure.

Investigation of Cover Seal Performance

Checking on the seal, the instruments and mechanisms of the stud tightening system, and those of monitoring system was exercised at the experimental plant the scheme of which is shown in Fig. 8. The experimental plant is constructed from details of the actual size and provided with all necessary tensometric equipment enabling to watch stressed states and temperature at various points of the structure when tested.

There were two phases of testing; at first, 50 cycles of raising the pressure up to 100 kg per sq.cm and dropping it down to 0 were done, then the experimental plant was repeatedly heated and cooled again with subsequent shortening the time of transition from one cycle to the other.

During these tests it was established that:

- the sealing unit assembly should be done precisely, the non-alignment of the cover and the flange should be within 0,1 – 0,2 mm;

- the sealing gasket can be used repeatedly several times;

- the monitoring cool-heat system of the thrust ring defreases a stud bending moment and when necessary can maintain them at a level of stationary operating duty;

the sealed joint between the cover and the flange performs well at all the conditions created up to one at which it was being cooled at the rate of $120^{0}C$ per hour;

- the stressed state of the units and details of the vessel upper part under various conditions is determined.

It is found that the rate of cooling provided by the design with regard to vessel strength is permissible;

- a degree of stud tightening providing complete impermeability of the joint being equal to 0,7 - 0,9 mm, measured by the indicator, or was equivalent to the total $P_{tightening} = 1{,}5\, P_{hydraulic}$, where

$P_{tightening}$ - the total force of tightening of all 60 studs;

$P_{hydraulic}$ - the force effecting the cover caused by the internal pressure.

Control Checking of Vessel State at Manufacturing Plant

For primary reactor vessels as a necessary test at their hydraulic testing tensometric measurements should be done, their accounting results are to be included into a test report and accepted by the Gostekhnadzor services. From the viewpoint of using this data for subsequent operational purposes they can be very helpful at making a final decision where to position tensometers by means of which the operational personnel control the reactor duties at starting it up and shutting it down.

At the hydraulic test of the vessel stress measurements have been done at those points where by technical reasons it is not possible to measure them on the model or at the experimental plant. The total number of tensometers does not exceed 100.

5. FABRICATION AND QUALITY CHECKING

ORGANIZATION OF INVESTIGATION WORK ON TECHNOLOGY

Initiating the investigation work on checking the technology of the chosen metal the decision was made that the development of fabrication technology of ingots, forgings and plates, the development of welding and welding material technology as well as working out the technique of quality control should be displayed at the manufacturing plant on standard size details and units at close cooperation with the research institutes and designing agencies.

The problems of fabricating forgings and plates as thick

as 600 mm with insignificant distribution of mechanical properties throughout their thickness, and choosing a reliable technique to check their quality were to be solved. For welding work it was necessary to develop the technique of manual and automatic welding of the ring portions from alloyed steel with welded metal cover as well as the technique of defected weld repair. In the field of thermal treatment such conditions were to attain which would provide the given mechanical properties of the base metal and welded joints with an insignificant guaranteed level of residual stresses in the structure at the same time. In the field of checking it was necessary to show the significance of various defects, their influence on the structure strength, and to accumulate statistical data in order that on this basis to work out standards of the structure quality estimation. The program of this research work was the most expensive and overwhelming.

Fabrication of half-finished products

To attain the required mechanical properties forgings and relates were hardened with a subsequent temper-hardening. At welding the vessel steel it became clear that in order to attain good quality of welded joints with the required mechanical properties of the weld, to weld with post- annealing of overhardened zone, and to releave stresses, repeated annealing was necessary. That is why at the initial state the base metal (forgings, plates) had increased volumes of its yield limit and strength limit, so that post-annealing could provide the required properties.

Fabrication of vessel details

All the main vessel details and units, i.e. the flange, the strengthening ring, the ring portions of the nozzle zone and the middle vessel part, the thrust ring, the cover fastenings, nozzles, are made from forgings. The vessel bottom is fabricated of two plates, each 120 mm thick, welded one to the other by electric slag welding with a subsequent press forging. Thermally nontreated plates were used as blanks for the vessel bottom. Prior to welding the plates were carefully checked for the absence of flakes. After electric slag welding, the blank was treated thermally (hardening and annealing) to attain uniform mechanical properties of the base metal and

welded seam, then it was carefully checked ultrasonically from on the whole surface. On the forged bottom only bevels for welding with the cylindrical vessel portion were machined.

The ring portions of the middle vessel part, the same of the nozzle zone, the flange, also the strengthening ring and the thrust ring were fabricated from one forging each by means of mechanical machining.

After machining every blank was tested by ultrasound for the absence of flakes and other defects.

Welding work

At the fabrication the vessel was devided into three technological units: the bottom with the ring portion, two ring portions of the middle part, and the two ring portions of the flange zone with the flange. Welding the details in each unit, as well as welding the units, was made with the accompanying heating the details at the place of welding by means of special machines with welding and heating devices. The welding work was done mainly by machines. Having welded ring joints the unit was thermally treated (annealed) in the furnace to provide the required for the welded joint properties.

All around welded joints and the zones ajoining to the welded details after welding and thermal treating were carefully checked by X-rays and ultrasonically.

Before welding vessel units each to other the internal surface of every unit was covered with protective welded stainless metal. In order to provide high quality welded metal layer prior to commencing the work on covering the surface with the metal, the selection of electrodes and welding materials with required properties was finished as well as the preliminary working out of welding conditions and quality testing on samples. All internal surface was covered with welded metal except the space ajoining to bevels to be welded after. This space was welded when the unit welding had been already made. The check of mechanical properties of butt welds was depplayed by testing the samples cut out from the control plates welded simultaneously with the make up of control welds using same initial materials, welding technique, conditions and thermal treatment.

To provide necessary accuracy of geometrical dimentions of the vessel the details and the units of the vessel were fi-

nally machined as a rule after welding and heat-treating. Much attention was payed to each detail and unit aiming at the accuracy of dimentions provided. As a result the alignment of the vessel along the vertical axis was not more than 8 mm at a length of 11 m.

Strengthening ring setting; other checks

Setting the strengthening ring on the flange of the finished welded and tested vessel was done with 1,5 mm strain per side. Prior to setting the strengthening ring was heated in the furnace. Due to a very accurate machining of the sitting places of the ring and the flange after setting the ring the vessel neck had an insignificant ellipticity of 0,2 mm over the cover diameter.

In fabricating the vessel cover, thrust ring, fastenings, nozzles, etc. a careful check was exercised at every stage of the fabrication especially for flakes and some other hidden defects.

The fabricated vessel when a control assembly was subjected to a hydraulic test at the manufacturing plant with a simultaneous check of the stressed state of all major elements of the vessel by means of tensometers.

6. CONCLUSION

The experience of the fabrication has shown that the reactor vessel made at the plant provides for sufficient reliability of operation proved by the technological tests and the design and the investigation on samples, models, natural scale stand and other fabricated articles.

REFERENCES

I. Водо-водяные энергетические реакторы (ВВВЭР) в СССР Скворнов С. Доклад № 2518 на II Международной конференции по мирному использованию атомной энергии, Женева, 1958 г.

2. Канторович Э.Б. "Основы расчета химических машин и аппаратов" Машгиз 1960 г.

3. Котлонадзор "Справочник по котлонадзору" Госэнергоиздат, 1951.

4. Корндорф Б.А. "Техника высоких давлений в химии". Госхимиздат

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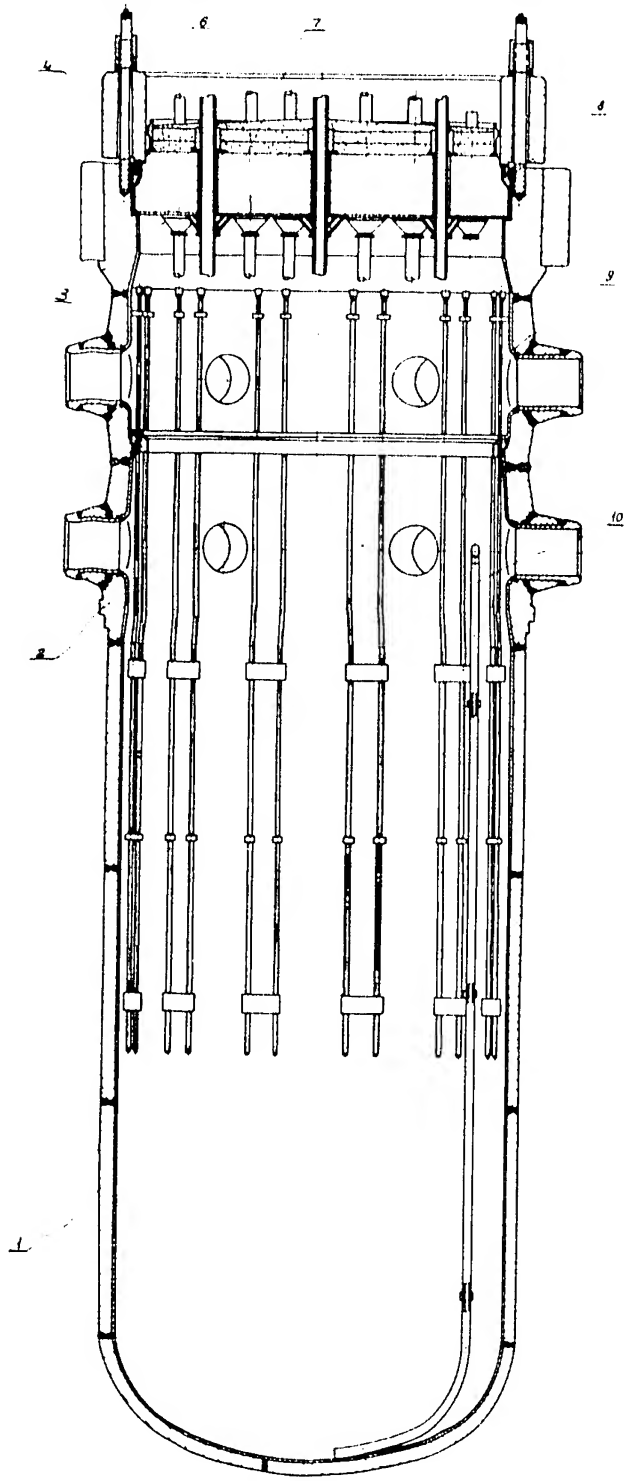

Fig. 1. The reactor vessel of the New-Voronezh APS.
1 - lower zone; 2 - middle zone; 3 - upper zone; 4 - thrust ring; 5 - stud; 6 - nut; 7 - cover; 8 · wedge -shaped gasket; 9 - channels for loading vessel metal samples; 10 - discharge and blowing tube; 331

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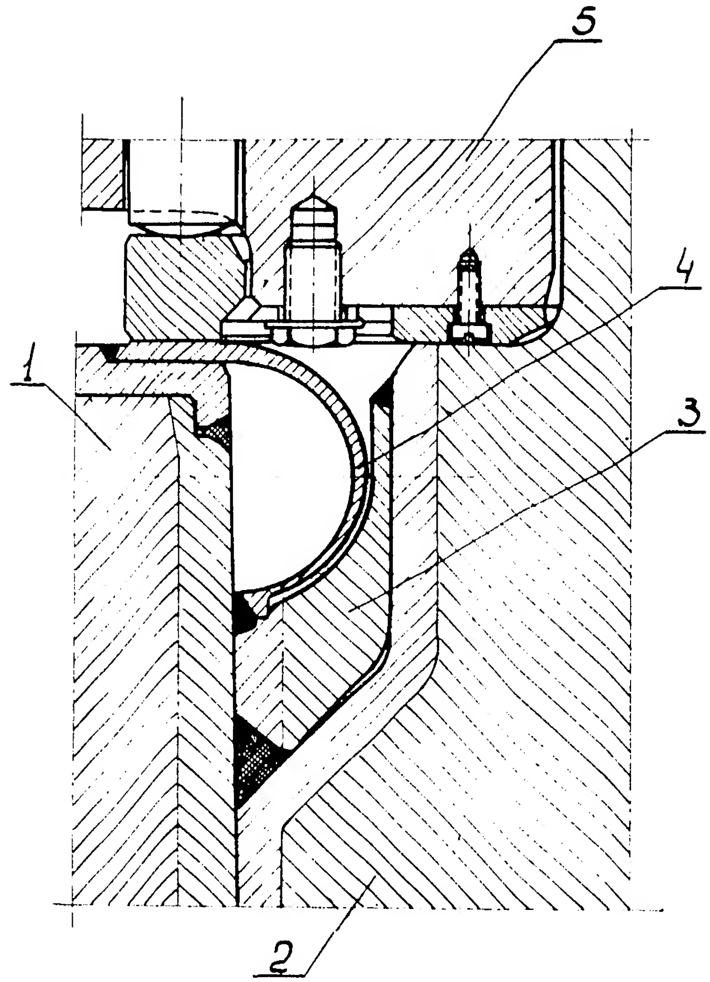

Fig. 2. The emergency sealing.
1 - flange; 2 - cover; 3 - enclosure; 4 - half-a-torus compensator; 5 - thrust ring:

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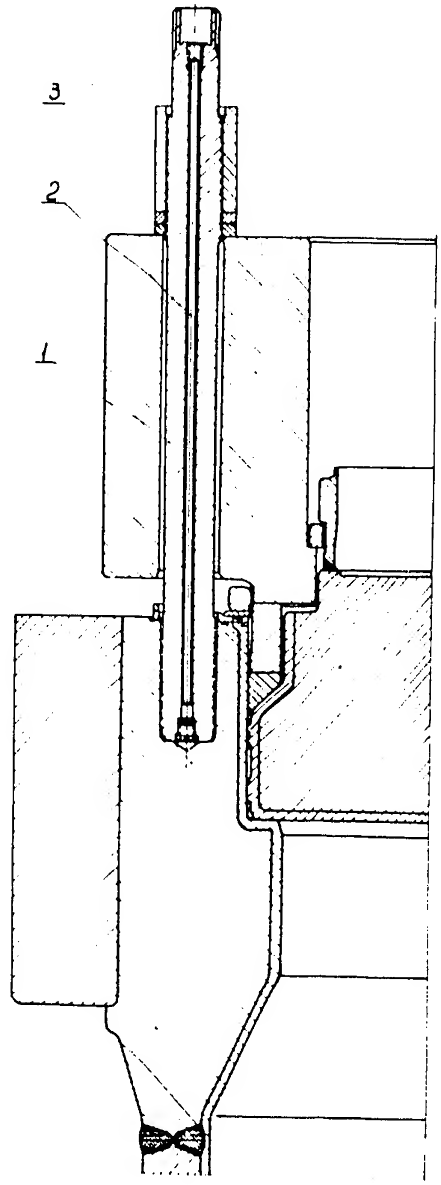

Fig. 3. 1 - The device controlling the extention of a stud.
1 - stud; 2 - gauge; 3 - indicator socket;

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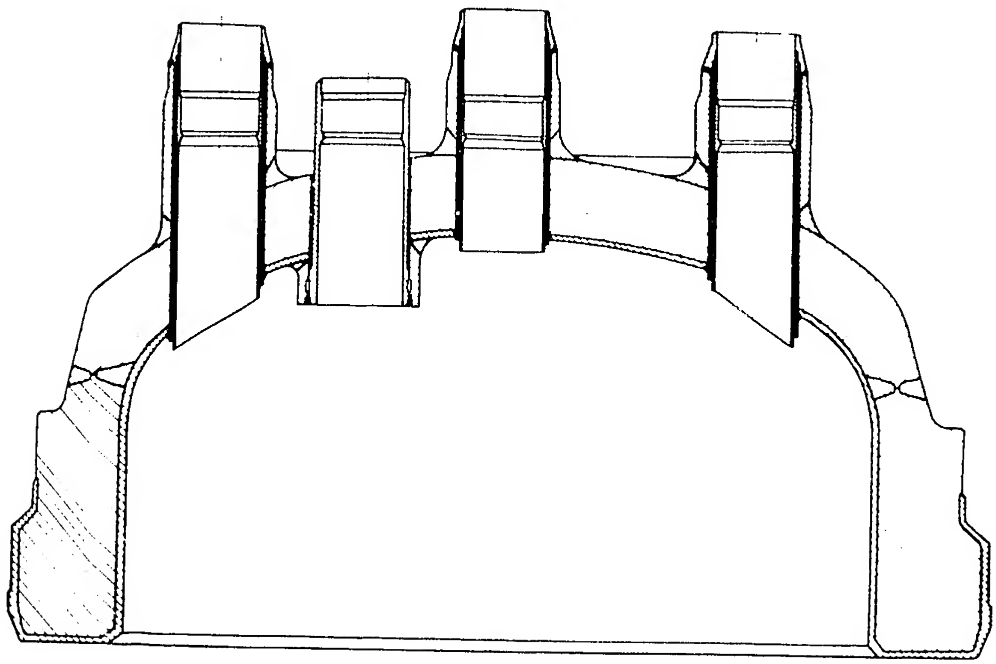

Fig. 4. The cover the reactor supplied to the German Democratic Republic.

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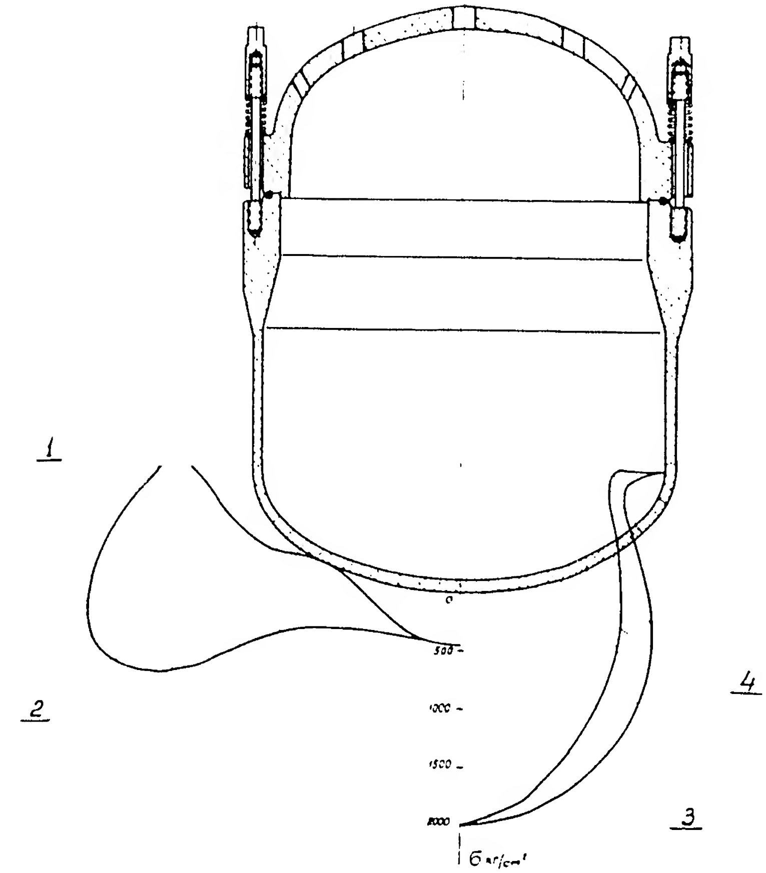

Fig. 5. The vessel model from resine and the diagram of bottom stresses:

1 – ring stresses across the inside contour;

2 – meridian stresses across the inside contour;

3 – meridian stresses across the outside contour;

4 – ring stresses across the outside contour;

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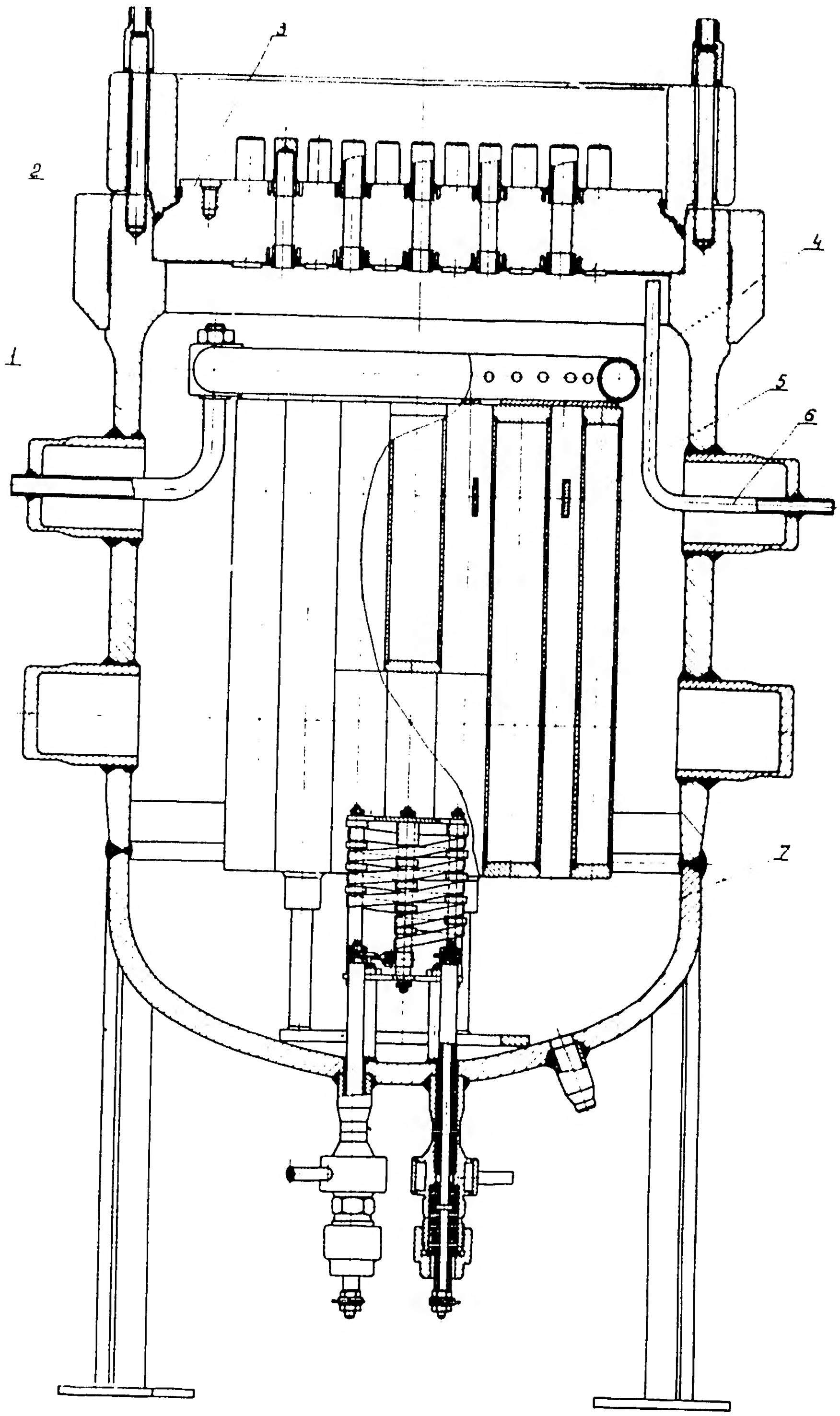

Fig. 6. The steel vessel model of the New-Voronezh APS.
1 - vessel; 2 - thrust ring; 3 - cover; 4 - cooler;
5 - displacer; 6 - ventube; 7 - electric heater;

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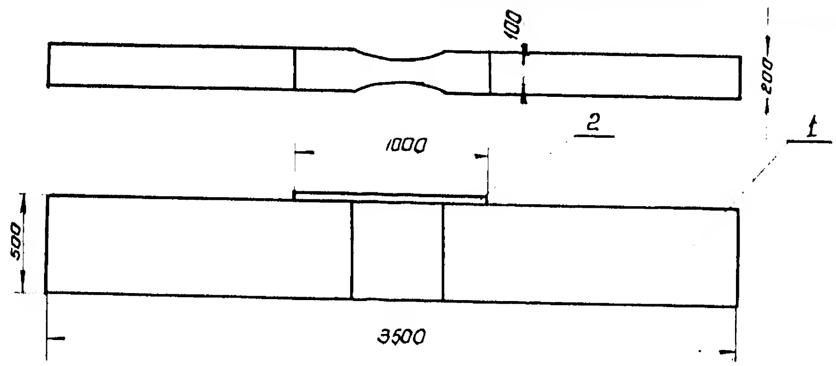

Fig. 7. The sample of larger size:
1 - base metal; 2 - welded metal;

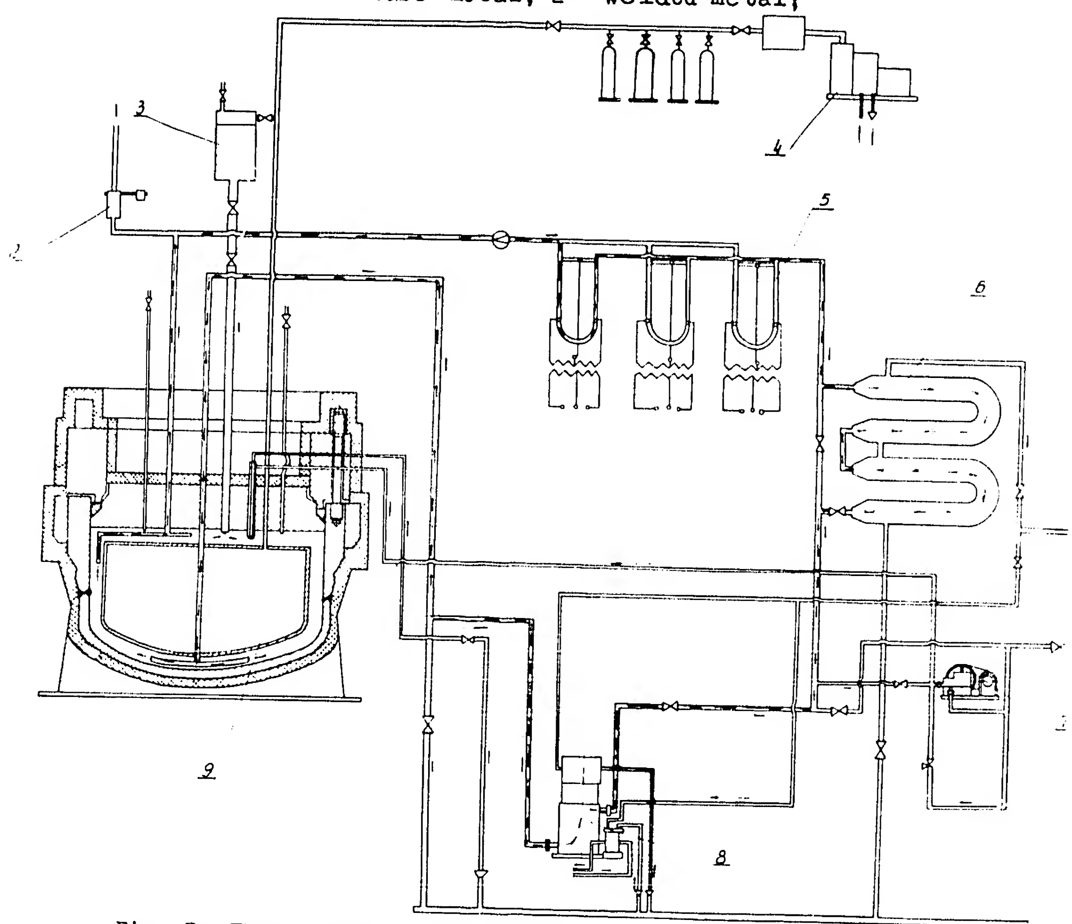

Fig. 8. The natural scale stand :
1 - vessel model of actual size; 2 - safety valve; 3 - cold water tank; 4 - compressor; 5 - electric heaters; 6 - heat exchangers; 7 - feed pump; 8 - circulation pump; 9 - displacer.

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